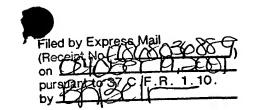# DRAWING METHOD FOR DRAWING IMAGE ON TWO-DIMENSIONAL SCREEN

The subject application is related to subject matter

5   disclosed in the Japanese Patent Application No. Tokugan

2000-399461 filed on December 27, 2000 and Tokugan

2001-236325 filed on August 3, 2001 in Japan, based on which

this application claims priority under the Paris

Convention and which is incorporated by reference herein.

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BACKGROUND OF THE INVENTION

1.   Field of the Invention

The present invention relates to a drawing method for

drawing an image on a two-dimensional screen such as on

15   a television monitor device and a drawing device therefore,

a computer readable recording medium having recorded

therein a draw processing program to be executed on a

computer, a program execution device for executing the draw

processing program, and a draw processing program to be

20   executed on a computer.

2.   Description of the Related Art

There are accelerating trends toward higher

integration and higher speed as for processors, memories

25   and so forth of recent television game machine and personal

computer.   Such advancement enables real-time generation

of a three-dimensional image having an excellent presence and perspective (feel of depth) and display thereof on a two-dimensional monitor screen.

For the case a three-dimensional image is drawn on a two-dimensional monitor screen, it is a general practice to subject a three-dimensional polygonal data to geometric processing such as coordinate transformation, clipping and lighting, and the obtained data are then transformed by perspective projection transformation.

For the case a three-dimensional image is drawn on a two-dimensional monitor screen, a widely adopted technique for expressing perspective or reducing affection by flicker caused by shrunk drawing of distant polygons is such that drawing the image in focus at a portion close to a virtual viewpoint but blurred at a portion distant from the virtual viewpoint.

In a conventional method for drawing a blurred image depending on the distance thereof from the virtual viewpoint, an original image are, for example, stepwisely shrunk corresponding to the distance from a virtual viewpoint and then enlarged again, and the enlarged images is synthesized with the original image according to distance in the depth direction (Z value) from the virtual viewpoint set for every pixel.

Such stepwise shrinking depending on the distance from the virtual viewpoint and corresponding enlargement,

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however, increases a load of image processing by the CPU, which will adversely affect other processing in progress of a game.

On the other hand, reducing the number of steps of shrinking and enlargement in the blurring in order to reduce the load of the CPU will be unsuccessful in obtaining a desired blurring effect and will thus fail in obtaining a desirable perspective.

SUMMARY OF THE INVENTION

The present invention was proposed to address the foregoing problems, and an object thereof resides in that providing a drawing method, a drawing device, a computer readable recording medium having recorded therein a draw processing program to be executed on a computer, a program execution device for executing the draw processing program, and a draw processing program to be executed on a computer; all of which are aimed at reducing load on a CPU when an image is drawn as being blurred depending on distance from a virtual viewpoint, and at obtaining a desired blurring depending on the distance from the virtual viewpoint to thereby create a desirable perspective.

In the present invention, a value for expressing distance from a virtual viewpoint is set for every compositional unit of a first image, a second image is generated, a coefficient corresponding to such value for

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expressing the distance set to every predetermined compositional unit is defined, and the first image and the second image are then synthesized based on the coefficient defined for every predetermined compositional unit.

5   In particular in the present invention, the first image is blurred to generate the second image, and the first image and the second image are synthesized using a semi-transparent coefficient such that increasing a ratio of the second image as the distance from the virtual

10   viewpoint increases, so that an image can be obtained as being in focus at a portion close to a virtual viewpoint and blurred to a larger extent at a portion apart further from the virtual viewpoint.

        Other and further objects and features of the present

15   invention will become obvious upon understanding of the illustrative embodiments about to be described in connection with the accompanying drawings or will be indicated in the appended claims, and various advantages not referred to herein will occur to one skilled in the

20   art upon employing of the invention in practice.

BRIEF DESCRIPTION OF THE DRAWINGS

        Fig. 1 is a block diagram showing an exemplary schematic constitution of a major portion of a drawing

25   device according to an embodiment of the present invention;

        Fig. 2 is a chart for explaining a general CLUT (Color

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Look-Up Table);

Fig. 3 is a chart for explaining index for defining R, G and B from the CLUT;

Fig. 4 is a chart for explaining CLUT containing

5   gradational α values;

Fig. 5 is a chart for explaining a Z value expressed in three bytes;

Fig. 6 is a graph for explaining a case in which the second byte of the Z value is adopted as an index for

10 defining the α value from the CLUT of this embodiment;

Fig. 7 is a flow chart showing a schematic process flow in a draw processing in this embodiment;

Fig. 8 is a chart showing an exemplary current image before being added with perspective;

15 Fig. 9 is a chart showing an exemplary blurred image obtained by entirely blurring the current image;

Fig. 10 is a chart showing an exemplary image having a natural perspective generated by the draw processing of this embodiment; and

20 Fig. 11 is a block diagram showing a schematic constitution of a personal computer for executing a draw processing program whose process flow was shown in Fig. 7.

25 **DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS**

Various embodiments of the present invention will be

described with reference to the accompanying drawings. It is to be noted that the same or similar reference numerals are applied to the same or similar parts and elements throughout the drawings, and the description of the same

5 or similar parts and elements will be omitted or simplified.

Constitution of Drawing Device According to the Present Embodiment

Fig. 1 shows an exemplary schematic constitution of a major portion of a drawing device 1 according to an

10 embodiment of the present invention.

The drawing device 1 now in this embodiment is such that for drawing a two-dimensional image based on texture mapping onto three-dimensional polygons, and is applicable, for example, to television game machine, personal computer

15 and three-dimensional graphical device (in particular to so-called graphic synthesizer).

The drawing device 1 of this embodiment shown in Fig. 1 mainly comprises a luminance calculation/coordinate transformation unit 2, an LOD (Level OF Detail) calculation

20 unit 3, a texture coordinate calculation unit 4, a DDA (Digital Differential Analyzer) unit 5, a pixel engine 6 and an image memory 7.

The image memory 7 further comprises the individual storage regions, that is, a Z buffer 8 for storing values

25 in the depth direction from a virtual viewpoint (typically expressed with 3 byte, 24 bits in total), a texture buffer

9 for storing data such as texture for generating by mapping an entire color and pattern on polygons and CLUT (Color Look-Up Table), and a frame buffer 10 for storing and synthesizing frame data displayed on a two-dimensional
5   monitor screen.

To an input terminal 13 of the drawing device 1 provided with such components, various information for drawing a three-dimensional image, such as those for polygon, texture, light source and viewpoint, are entered.
10   Such various information is supplied through a communication line, storage device and so forth.

The three-dimensional polygon information comprises those, for example, of coordinates (x, y, z) for the individual vertices of a triangular polygon and normal
15   lines at the individual vertices; and the viewpoint information and the light source information are those for enabling luminance calculation and coordinate transformation with regard to such polygon. Now the light source information is by no means limited to that for
20   expressing information for a single light source but also may be such that expressing information for a plurality of light sources.

The texture information comprises information for texture coordinate corresponding to the individual
25   vertices of the triangular polygon and CLUT used for expressing color or pattern.

The CLUT herein is composed of a three-primary-color table for R (red), G (green) and B (blue), and an α value table. The three-primary-color table is used for defining colors of the individual pixels in the texture. The α

5   value is a coefficient for expressing semi-transparency, which is responsible for defining a radio of image blending (α blending) when the texture is mapped. In this embodiment, the α values in the CLUT are graded in a plurality of steps, where details of which will be described

10   later. The table number of the CLUT and the α value are correlated so that a larger table number corresponds to a smaller (or a larger) α value.

An index for withdrawing three-primary-color values for R, G and B from the CLUT (that is, a value for designating

15   a table number of the CLUT) is set for every pixel expressed by an XY coordinate of the texture. In particular for the case of this embodiment according to the present invention, while details of which will be described later, the second byte of the Z value (expressed with 3 bytes, 24 bits in

20   total) for the individual pixels is used as an index for withdrawing the α value from the CLUT. In this embodiment, the Z value is set so as to be smaller as the distance from a virtual viewpoint becomes larger.

Such a variety of information is first entered into

25   the luminance calculation/coordinate transformation unit 2 of the drawing device 1.

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The luminance calculation/coordinate transformation unit **2** transforms the entered individual coordinate information of polygons into coordinate values in another coordinate system for two-dimensional drawing, and

5 calculates the luminance at the individual vertices of the polygons based on the viewpoint information and light source information. The luminance calculation/coordinate transformation unit **2** is also responsible for other processing beside such calculation. The individual values

10 calculated by the luminance calculation/coordinate transformation unit **2** are then entered into the LOD calculation unit **3**.

The LOD calculation unit **3** calculates an LOD (Level Of Detail) value, which is used when the pixel engine **6**

15 reads out a texture from the texture buffer **9**, using the Z coordinate of thus-transformed polygon. Now the LOD value is a value calculated from a reduction ratio according to which the polygon is shrunk, and typically obtained as a logarithmic value of a distance from the viewpoint to

20 the polygon. The obtained LOD value is then sent via the DDA unit **5** to the pixel engine **6**.

The texture coordinate calculation unit **4** calculates a texture coordinate value used when the pixel engine **6** reads out a texture from the texture buffer **9**. The obtained

25 texture coordinate value is then sent via the DDA unit **5** to the pixel engine **6**.

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The DDA unit **5** transforms the two-dimensional polygon vertices information, Z coordinate values, luminance information and so forth into pixel information. More particularly, for the individual pixels, coordinate values thereof, Z values, luminance values and texture coordinate values are sequentially defined based on linear interpolation. The output from the DDA unit **5** is then sent to the pixel engine **6**.

The pixel engine **6** controls read/write operations to or from the Z buffer **8**, texture buffer **9** and frame buffer **10**; and is also responsible for texture mapping, comparison of Z coordinate values, pixel value calculation and so forth.

The pixel engine **6** not only withdraws three-principal-color data of R, G and B from the CLUT corresponding to the index of the texture to thereby set color for the individual pixels, but also withdraws α values, which is later used for α blending, from the CLUT using the second byte of the Z value of the individual pixels, detailed process flow of which will be described later.

The pixel engine **6** is also responsible for various processing such as scissoring, dithering and color clamping. The scissoring refers to a processing for removing data overflowed from the displayable area; the dithering refers to a processing for complicating arrangement of each color in order to express many colors

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using only a small number of principal colors; and the color clamping refers to a processing for limiting the calculated color value so as not to exceed 255 or become smaller than zero.

5   Image data obtained after such processing by the pixel engine **6** are stored into the frame buffer **10** to thereby generate frame data to be drawn on the two-dimensional monitor screen (two-dimensional image data), and such two-dimensional image data is then read out from the frame

10   buffer **10**, output from an output terminal **14**, and sent to the two-dimensional monitor device.

Draw Processing of the Embodiment

        Details of the CLUT according to this embodiment, setting of texture color or pattern using such CLUT, and

15   the α blending will be explained in comparison with setting of texture color or pattern using a general CLUT and the α blending.

Typical Draw Processing using General CLUT

        Prior to explanation of an exemplary drawing using

20   CLUT according to this embodiment, relation between the three-principal-color data for R, G and B and α value in a general CLUT will be explained. Fig. 2 shows a typical example of a general CLUT, and Fig. 3 shows an XY coordinate of individual pixels composing the texture and an example

25   of indices for defining color or pattern of such individual pixels.

The CLUT shown in Fig. 2 comprises table numbers (No.),
color data for R, G and B, and α values (values listed in
column "A"). The table numbers, color data for R, G and
B, and α values are respectively expressed in hexadecimal

5 numbers. The table numbers are those specified by the
index of the individual pixels; values of the color data
for R, G and B indicate levels of such three principal
colors; and α values indicate the degree of
semi-transparency.

10 Referring now to Figs. 2 and 3, index "00" in Fig.
3 corresponds to table No. "00" in Fig. 2; index "01" to
table No. "01"; index "02" to table No. "02"; index "03"
to table No. "03" and so on. The individual pixels having
index of "00" in Fig. 3 are assigned with a color of R (red),

15 which is apparent from Fig. 2 showing that table No. "00"
corresponds to "ff" for R, "00" for G and "00" for B.
Similarly, the individual pixels having index of "01" in
Fig. 3 are assigned with a color of G (green), which is
apparent from Fig. 2 showing that table No. "01" corresponds

20 to "00" for R, "ff" for G and "00" for B. Thus an exemplary
texture drawn according to Figs. 2 and 3 appears as a green
cross on a red background.

According to the CLUT shown in Fig. 2, the individual
pixels having index of "00" in Fig. 3 are assigned with

25 an α value of "80" which is corresponded to table No. "00"
in Fig. 2, and similarly, the individual pixels having index

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of "01" in Fig. 3 are also assigned with an α value of "80" which is corresponded to table No. "01" in Fig. 2. Such α value of "80" represents a degree of semi-transparency of approx. 0.5 (i.e., 50%), so that the green cross on the red background is drawn so as to overlap an already-drawn image in a 50% transparency.

As is clear from the above, using the general CLUT and indices shown in Figs. 2 and 3 allows determination only of color or pattern of the texture and the ratio of image blending in the α blending.

Typical Draw Processing using CLUT of the Embodiment

While Figs. 2 and 3 in the above showed a general CLUT and a typical use thereof, the embodiment of the present invention employs a CLUT having α values gradationally composed therein and a predetermined value in the Z value for the individual pixels as indices for defining the α values in the CLUT (the second byte of a three-byte Z value as shown in Fig. 5 in this embodiment) to thereby allow the α blending according to distance in the depth direction of drawn objects from a virtual viewpoint. Determination of color or pattern of the texture can be proceeded as described in the above referring to Figs. 2 and 3.

That is, in this embodiment, the α values in the CLUT are gradationally set so that the larger value thereof corresponds to higher semi-transparency (lower

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transparency), and the second byte of the Z value, whose value decreases as the distances from the virtual viewpoint increase, is used as an index for selecting the α values, to thereby determine an α plane. The α blending, using

5 such α plane, of a current image and a blurred image thereof, for example, can provide an image in which an object or the like close to the virtual viewpoint is in focus and those apart from the virtual viewpoint are gradually blurred as the distance from such virtual

10 viewpoint increases.

In other words, the embodiment can provide an image in which an object or the like close to the virtual viewpoint is well focused and those apart from the virtual viewpoint are gradually blurred as the distance from such virtual

15 viewpoint increases, just like an image obtained by photographing while focusing on an object close to the viewpoint under setting of a shallow depth of field, where even objects or the like apart from the focal position retain the color to thereby attain a natural perspective.

20 Such image totally differs from a pan-focal image well focused irrespective of the distance from a viewpoint, which is obtainable by photographing using a photographic optical system while setting a large depth of field of a photographing lens.

25 A reason why in this embodiment the second byte of the Z value expressed with 3 bytes (24 bits) as shown in

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Fig. 5 is used as an index for defining the α values of

the CLUT shown in Fig. 4 is that the amount of change of

the Z value is in inverse proportion to that for bit values

in the individual bytes as shown in Fig. 6. As is clear

5   from Fig. 6, using the least significant byte of the Z value

will result in too large changes in the bit values, and

looping of the bit value may occur in a worst case in which

the same bit values may repetitively be generated. On the

other hand, using the most significant byte of the Z value

10   will result in too small changes in the bit values. Thus

the second byte of the Z value is to be used as an index

for defining the α values of the CLUT.

That is, when a predetermined byte of the Z value is

used as an index for defining the α values, too large

15   changes in the index designated by such predetermined byte

result in large changes also in the α values defined by

such index, which undesirably sharpens changes in the α

-blended image and ruins the natural perspective. When the

looping of bits in the predetermined byte should occur,

20   an appropriate relation between the distance from the

virtual viewpoint and the α value can no more be retained

and the obtained image will be denaturalized badly. On the

other hand, too small changes in the index designated by

such predetermined byte result in too small changes in the

25   α values defined by such index, which only produces no

significant change in the resultant α-blended image and

fails in producing a desirable perspective. For such reasons, the second byte of the Z value is used as an index for the α values in this embodiment, which can yield an appropriate perspective.

5 <u>Flow of Draw Processing using CLUT and Z Values in the Embodiment</u>

The following paragraphs describe, referring to a specific example of the drawing, a process flow of the draw processing capable of obtaining natural perspective by

10 using the CLUT according to this embodiment (CLUT having gradationally composed α values) and the second byte of the Z value as an index for the α values.

Fig. 7 shows a schematic flow of the draw processing according to the embodiment. It should now be noted that

15 the processing described below is such that being executed mainly by the pixel engine **6** using data stored in the image memory **7**.

As shown in Fig. 7, the pixel engine **6** first in step **S1** draws a current image (a first image in the present

20 invention) into the frame buffer **10**, and writes a Z value in the Z buffer **8**.

The current image herein comprises a "mountain" object **20**, a "house" object **21** and a "human" object **22**, where the "mountain" object **20** is placed most apart from

25 a virtual viewpoint, the "human" object **22** is placed close to the virtual viewpoint, and the "house" object **21** is

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placed at an intermediate point therebetween, as shown in Fig. 8. A background image other than these objects is omitted herein for simplicity of the explanation.

The pixel engine **6** next in step **S2** generates a blurred image of the current image (a second image in the present invention), and stores such blurred image into another storage area in the frame buffer **10**. It is now also allowable to provide a separate frame buffer beside the frame buffer **10** and store the blurred image into such separate frame buffer. There is known a variety of techniques for producing the blurred image, and one example of which is such that synthesizing the current image with a slightly shifted image thereof.

The blurred image generated in step **S2** is composed, for example, of a blurred image **23** of the "mountain" object **20** shown in Fig. 8, a blurred image **24** of the "house" object **21** and a blurred image **25** of the "human" object **22**, as shown in Fig. 9. The degrees of the blurring of the blurred images **23**, **24** and **25** are the same.

The pixel engine **6** next in step **S3** reads out the α value from the CLUT shown in Fig. 4 using the second byte of the Z value, written in the Z buffer **8**, for the individual pixels in the current image shown in Fig. 8.

As has been described in the above, in the current image shown in Fig. 8, the "mountain" object **20** is most apart from the virtual viewpoint, the "human" object **22**

is most close to the virtual viewpoint, and the "house" object **21** is placed at an intermediate distance. So that the Z values for the individual pixels of the current image shown in Fig. 8 are largest for the pixels composing the

5   "mountain" object **20**, smallest for those composing the "human" object **22**, and intermediate for the "house" object **21**. When the second byte of such Z value is used as an index for withdrawing the α value from the CLUT shown in Fig. 4, the α value corresponding to the individual pixels is

10 largest for those composing the "mountain" object **20** (maximum degree of semi-transparency), smallest for those composing the "human" object **22** (minimum degree of semi-transparency), and intermediate for those composing the "house" object **21** (intermediate degree of

15 semi-transparency).

The pixel engine **6** next in step **S4** proceeds the α -blending of the current image shown in Fig. 8 and the blurred image shown in Fig. **9**, both of which being stored in the frame buffer **10**, using an α plane composed of the

20 α values read out in the process of step **S3**.

Since the degree of semi-transparency is largest for the individual pixels composing the "mountain" object **20**, smallest for those composing the "human" object **22**, and intermediate for those composing the "house" object **21** in

25 such α plane, an image obtained by α-blending of the current image shown in Fig. 8 and the blurred image shown

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in Fig. 9 is such that shown in Fig. 10.

More specifically, since the portion of the "mountain" object has the largest degree of semi-transparency, in which the blurred image accounts for a larger ratio than the current image, so that such object is drawn as a blurred image **26** as shown in Fig. 10. On the other hand, since the portion of the "human" object has the smallest degree of semi-transparency, in which the current image accounts for a larger ratio than the blurred image, so that such object is drawn as an in-focal image **28**. Since the portion of the "house" object has the intermediate degree of semi-transparency, so that such object is drawn as an image **27** not so well-focused than the image **28** but not so blurred than the image **26**.

It is now also allowable for the pixel engine **6** to practice the processing as shown by the flow chart of Fig. 7 on the hardware basis such as DSP (Digital Signal Processor), or on the software basis with the aid of draw processing programs such that being sent via a communication line such as CPU, or such that being read out by a storage device from a storage medium such as DVD or CD-ROM. In particular, a draw processing program used for the case that the draw processing by the pixel engine **6** is practiced on the software basis is such that sequentially executing the individual process steps explained referring to the flow chart of Fig. 7. Such draw

processing program can not only be installed previously as a processing program for the pixel engine **6**, but can also be entered through the input terminal **13** shown in Fig. 1 at the same time with, or in advance of entering the 5   polygon information.

As a specific example of a constitution for practicing the draw processing of this embodiment on the software basis, Fig. 11 shows a schematic constitution of a personal computer on which the draw processing program whose process 10   flow was shown in Fig. 7 is run.   Now in this embodiment, the draw processing program is mainly executed by a CPU **123** shown in Fig. 11.

In Fig. 11, a storage unit **128** comprises, for example, a hard disk and a driver therefore.   The hard disk has 15   stored therein an operating program; draw processing program **129** of this embodiment incorporated for example by installation from various recording media such as a CD-ROM and DVD-ROM, or downloading via a communication line; and various data **130** typically including graphic 20   information for polygon drawing, texture, Z value, general texture, color value and α value.

The communication unit **121** is a communication device responsible for data communication with the external, such as a modem allowing connection to an analogue public 25   telephone line, a cable modem allowing connection to a cable television network, a terminal adaptor allowing connection

to ISDN (Integrated Services Digital Network), and a modem

allowing connection to ADSL (Asymmetric Digital Subscriber

Line). A communication interface (I/F) unit **122** is an

interface device responsible for protocol conversion which

5   enables data exchange between the communication unit **121**

and an internal bus.

An input unit **131** is an input device such as a keyboard,

mouse and touch pad. A user interface (I/F) unit **132** is

an interface device for supplying signals from the input

10   unit **133** to the internal unit.

A drive unit **135** is a drive device capable of reading

various data and programs including the draw processing

program according to this embodiment from a recording

medium such as a card-type semiconductor memory. A drive

15   interface (I/F) unit **134** is an interface device for

supplying signals from the drive unit **135** to the internal

unit.

A display unit **137** is a display device such as a CRT

(cathode ray tube) or LCD (liquid crystal display). A

20   display drive unit **136** is a drive device responsible for

driving such display unit **137** for display.

A ROM **124** typically comprises a re-loadable

non-volatile memory such as a flash memory, and stores a

BIOS (Basic Input/Output System) and various initial set

25   values of the personal computer. A RAM **125** is a device

into which application programs read out from the hard disk

in the storage unit **128** or various data are loaded, and is used as a working RAM for the CPU **123**.

The CPU **123** controls the entire operations of the personal computer as well as executes the foregoing draw processing based on the operating system programs or the draw processing program **129** of this embodiment stored in the storage unit **128**. That is, in the constitution shown in Fig. 11, The CPU **123** executes the draw processing program of this embodiment, which is one of the application programs read out from the hard disk of the storage unit **128** and loaded into the RAM **125**, to thereby enable the draw processing described in the foregoing embodiment.

As has been described in the above, the embodiment can provide an image in which an object or the like close to the virtual viewpoint is well focused and those apart from the virtual viewpoint are gradually blurred as the distance from such virtual viewpoint increases, where even objects or the like apart from the focal position retain the color to thereby attain a natural perspective.

In the conventional drawing technique, blurred images were generated by multi-step shrinkage and the corresponding enlargement to thereby achieve the perspective, and such blurred images obtained from such multi-step processing were then synthesized with an original image, so that the amount of image processing could not be reduced. On the contrary in this embodiment, the

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perspective is achieved by α-blending the current image and a single blurred image using an α-plane comprising α values corresponding to the distances from the virtual viewpoint, so that the amount of image processing does not

5   increase even when the distance from the virtual viewpoint is expressed in 256 steps (1 byte), which desirably ensures load reduction for CPU and speed-up of the processing.

The embodiment described in the above is only part of the examples of the present invention. It is therefore

10   to be understood that the present invention may be practiced in any modifications depending on the design or the like otherwise than as specifically described herein without departing from the scope and the technical spirit thereof.

For example, while a case of α-blending the current

15   image and a blurred image using the α-plane was exemplified, such α-plane is also available for blending an arbitrary color with the current image, which produces an image in which the objects or the like seem to be fused into the arbitrary color as the distance from the viewpoint

20   increases. Such technique is advantageous in achieving fogging, in which an object is more heavily fogged as the distance thereof from the viewpoint increases. It becomes also possible to create a special effect by α-blending an arbitrary image and the current image using such α-plane.

25   While the α value was defined based on the Z value for every pixel in the above embodiment, it is still also

allowable to define the α-value according to the distance from the virtual viewpoint for every polygon or object.